Nucleon-nucleon partial wave analysis to 2.5 GeV

Richard Arndt, Chang-Heon Oh, Igor Strakovsky, and Ron Workman
Department of Physics, Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0435

and

Frank Dohrmann
I. Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 148
D-22761 Hamburg, Germany

Abstract

A partial-wave analysis of NN elastic scattering data has been completed. This analysis covers an expanded energy range, from threshold to a laboratory kinetic energy of 2.5 GeV, in order to include recent elastic *pp* scattering data produced by the EDDA collaboration at COSY. The results of both single-energy and energy-dependent analyses are described.

INTRODUCTION

This analysis of elastic NN scattering data updates our previous analysis(1) to 1.6 GeV in the laboratory kinetic energy. The present analysis extends to 2.5 GeV, which is the limit for elastic *pp* differential cross sections measured(2) by the EDDA collaboration using the cooler synchrotron at COSY.

Measurements with a laboratory kinetic energy near 2 GeV are particularly interesting as they correspond to a center-of-mass energy (2.7 GeV) which has been suggested(3) for a broad dibaryon resonance. Near this energy, a sharp structure has been recently reported in the polarization observable A_{yy}(4), and this was taken as support for such a resonance. A resonancelike structure, at about the same energy, has also been reported in a partial-wave analysis by Hoshizaki(5). The authors of Ref.(2) have considered this possibility, but find no evidence for a resonant excursion in their unpolarized cross sections. Polarization measurements expected from Saturne II and COSY will certainly help to clarify this issue.

THE DATABASE

Our previous NN scattering analyses(1) were based on about 13,000 *pp* and about 11,000 *np* data. In Ref.(2) the *pp* analysis extended up to a laboratory kinetic energy of 1.6 GeV; the *np* analysis was truncated at 1.3 GeV. The present database(6) is considerably larger due both to an expanded energy range for the *pp* system and the addition of new data at lower energies.

The database above 1.6 GeV is mainly comprised of cross section measurements, much of these coming from the EDDA collaboration(2). From this source, we have added differential cross sections ranging from 540 MeV to 2520 MeV in the proton kinetic energy and from 35° to 90° in the cm scattering angle. In constructing the database extension from 1600 to 2500 MeV, we reexamined a number of references in order to include higher energy data which had previously been neglected. This search netted additional data mainly from ANL (450 points) and Saclay (about 900 points). The *np* database has not been increased significantly and, as a result, we did not extend our analysis of the I = 0 system. New *np* polarized data have been produced mainly by TRIUMF (100 points). More details regarding a total database, it can be found in Refs.(6,7).

PARTIAL-WAVE ANALYSIS

Our first attempts to extend the range of the NN analysis used the parameterization scheme of Ref.(1). These were unsuccessful. The problem was traced to the basis functions used to expand our K-matrix elements. Many of these become nearly degenerate as the kinetic energy of the incoming nucleon increases to 2.5 GeV. As a result, a modified form was used in the present analysis. Apart from this difference, the formalism used here is identical to that used in Ref.(1). The reader is directed to Refs.(7,8) for details.

Our single-energy and energy-dependent (SM97) results for the dominant isovector and isoscalar partial-wave amplitudes are displayed in Fig. 1 and Fig. 2. (Single-energy analyses were done in order to search for structures which may be missing from the energy-dependent fit.) Here we also compare with our previous fit (SM94). In some cases, the changes are quite large. This is particularly true near the upper energy limit of SM94, and for the smaller partial waves. The effect of these changes can be clearly seen in Fig. 3, where we show how well the new EDDA data(2) are reproduced by both SM94 and SM97. The influence of this experiment is most pronounced in the forward direction above 800 MeV.

In general, we find little structure over the higher energy region. This reflects the smooth, and rather flat, total and reaction cross sections between 1.5 GeV and 2.5 GeV. Our fit to these quantities is displayed in Fig. 4. Note that the reaction cross sections were excluded from our fit. This verifies that the set of total, total elastic (deduced from differential cross sections), and reaction cross sections are self-consistent.

The present analysis actually gives an improved fit to the data below 1.6 GeV. This is due to the altered basis set, found necessary to fit the higher energy data. Numerical comparisons are given in Table 1. Here we see that the COSY data(2) comprise a large fraction of the total set above 1.6 GeV. The results of analyses with (SM97) and without (NM97) this data set show how influential these measurements have been in determining the amplitudes. (The fits SM97 and NM97 used identical parameterization schemes. Only the database was changed.) The COSY data contribute a χ^2/datum of 1.07 from SM97 and 5.6 from NM97. The NET χ^2 increased by 3498 when 2121 COSY data were added to NM97 and then re-analysed to produce SM97.

Table 1. *Comparison of present and previous solutions. Dataset A was used in the SM94 analysis(1). Dataset B contains all data (apart from the EDDA data(2)) used in generating solution SM97. See the text for details regarding the SM97 and NM97 fits.*

PWA	Data	χ^2/pp data	χ^2/np data
		(0-1600 MeV)	(0-1300 MeV)
SM94(1)	(dataset A)	22375/12838	17516/10918
SM94(1)	(dataset B)	22390/12889	18480/10843
SM97	(dataset B)	20910/12889	17400/10843
		(0-2520 MeV)	(0-2000 MeV)
SM97	(dataset B)	26460/14873	17440/10854
SM97	(EDDA dataset(2))	2278/2121	–
NM97	(dataset B)	25240/14873	17280/10854
NM97	(EDDA dataset(2))	11964/2121	–

SEARCH FOR LESSER STRUCTURES

Although our fit (SM97) is parameterized to be devoid of the resonance-like structures conjectured to lie around 2 GeV, it is possible to add such structures and then look for those observables which are most sensitive to such an inclusion. In Fig. 5 we illustrate how a ${}^1S_0$

structure at $W_r = 2.7$ GeV (elastic width is $\Gamma_e = 16$ MeV, inelastic width is $\Gamma_i = 67$ MeV) would affect A_{yy} and A_{zz}.

CONCLUSIONS AND FUTURE PROSPECTS

We have extended our *pp* partial-wave analyses nearly 1 GeV beyond the limit quoted in our previously published results(1). The present range has been selected to include all of the recent elastic *pp* cross section data measured by the EDDA group(2). We found that it was possible to simultaneously fit the *pp* total cross section data, in particular the precise data of Ref.(9), along with differential cross sections from the EDDA collaboration(2). The resulting reaction cross sections, which were not included in the fit, are quite well reproduced. The predicted reaction cross sections are consistent with the results of Ref.(10) at lower energies, but deviate from these and follow the results of Ref.(11) above 1 GeV. While we find that the partial-wave amplitudes above 1.6 GeV are smooth and structureless, reflecting the behavior seen in the total and elastic cross section data, we have also considered the effect of more localized structures reported in polarization measurements(3,4). As the high energy region was constrained mainly by cross section data, the present solution should be considered as a guide to the expected amplitudes.

acknowledgments

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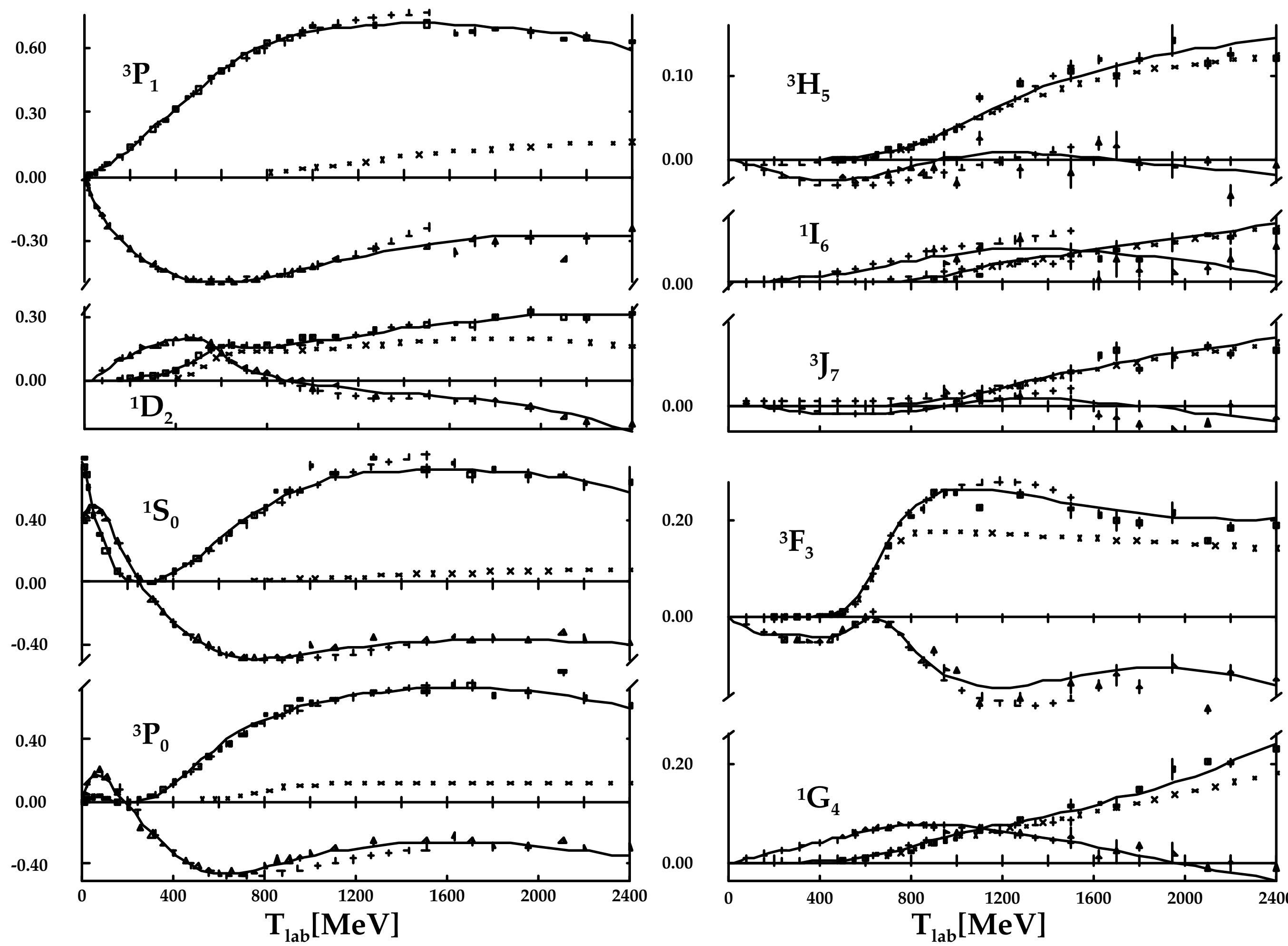
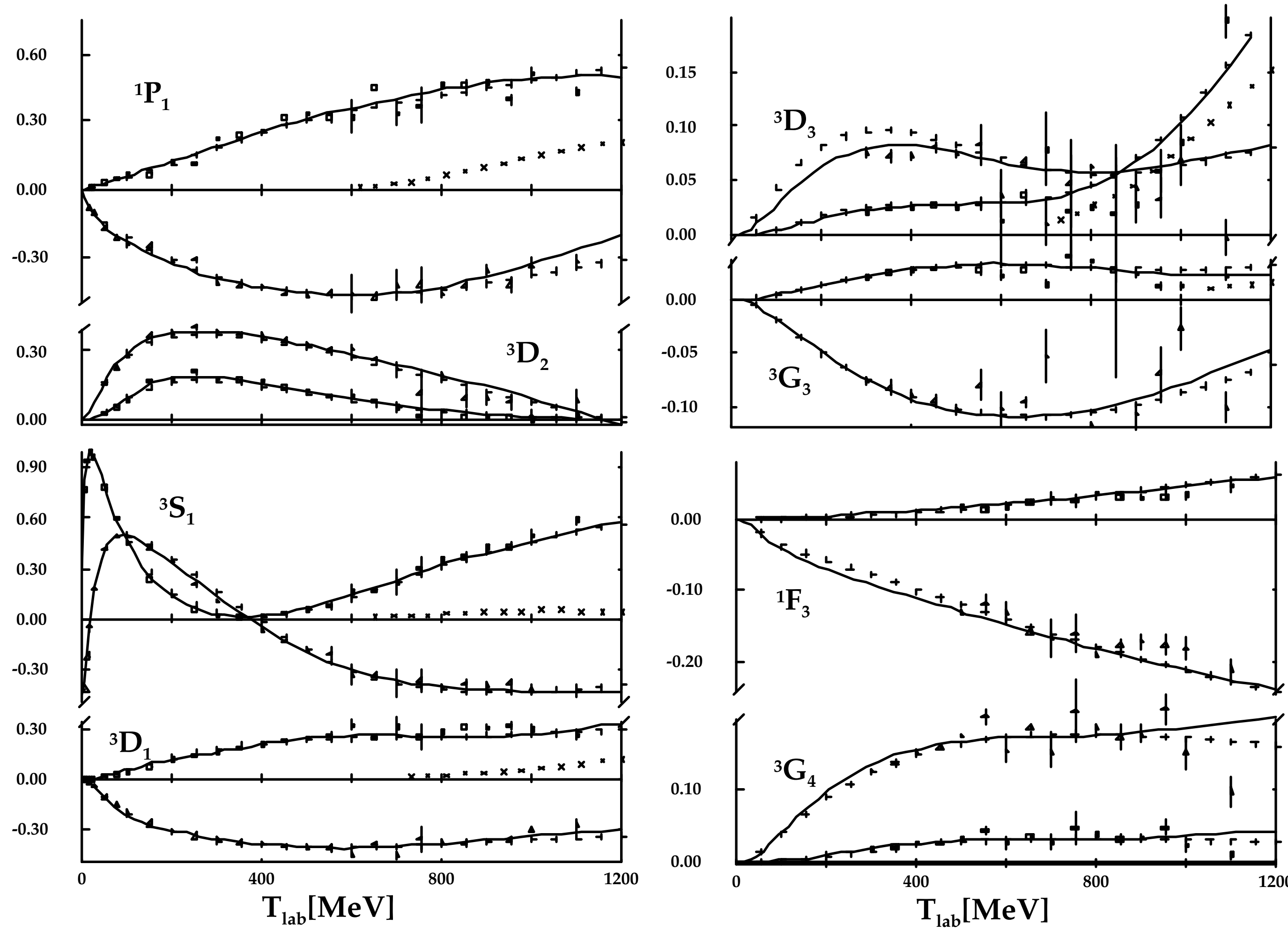


$^3P_1$
$^1D_2$
$^1S_0$
$^3P_0$
$^3H_5$
$^1I_6$
$^3J_7$
$^3F_3$
$^1G_4$
T_{lab}[MeV]
T_{lab}[MeV]



$^1P_1$
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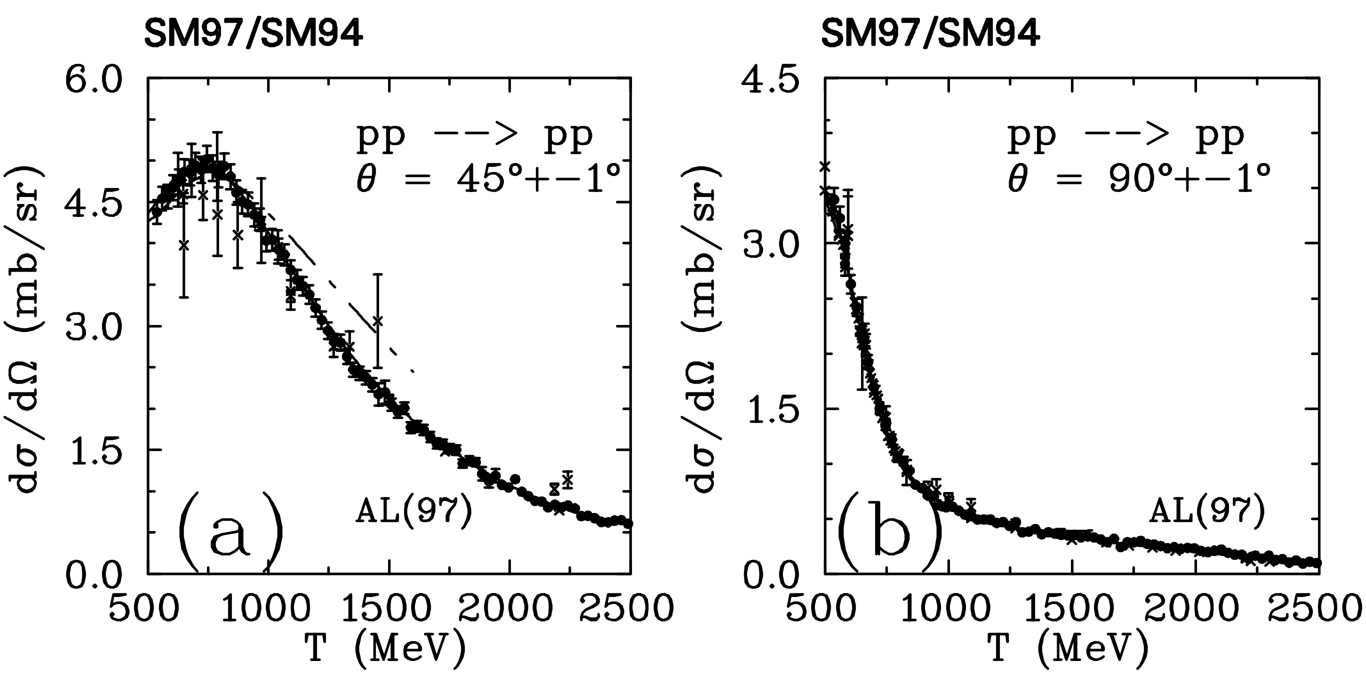
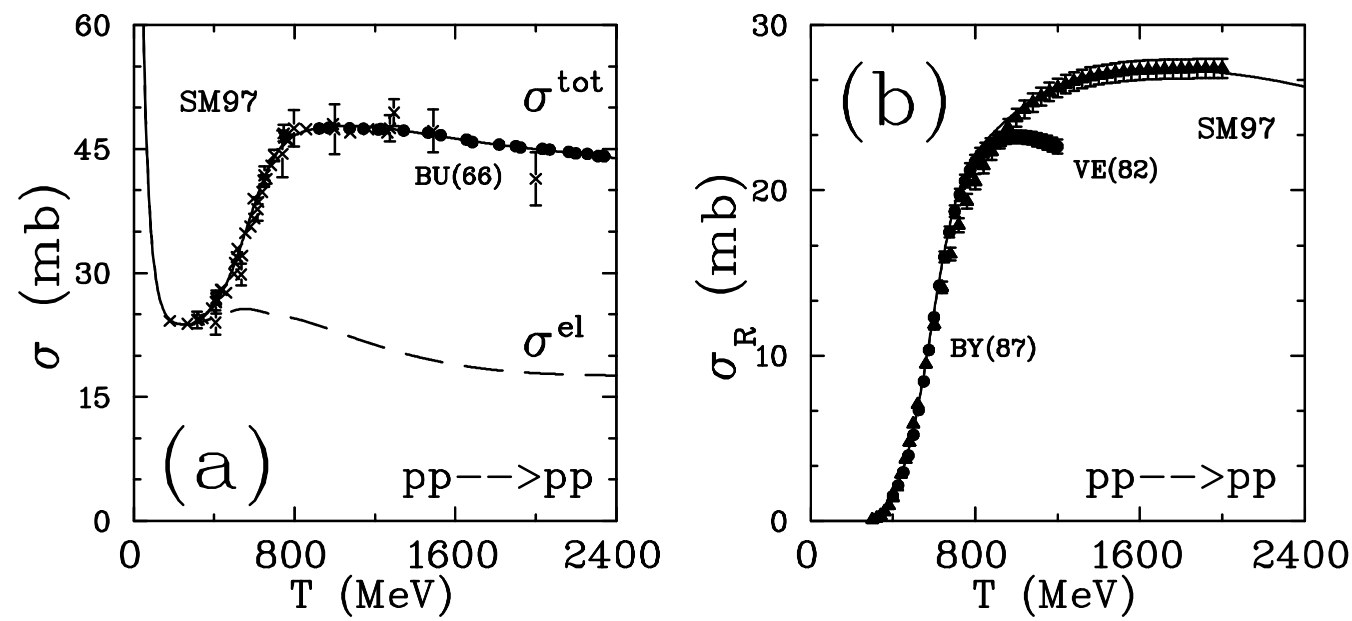
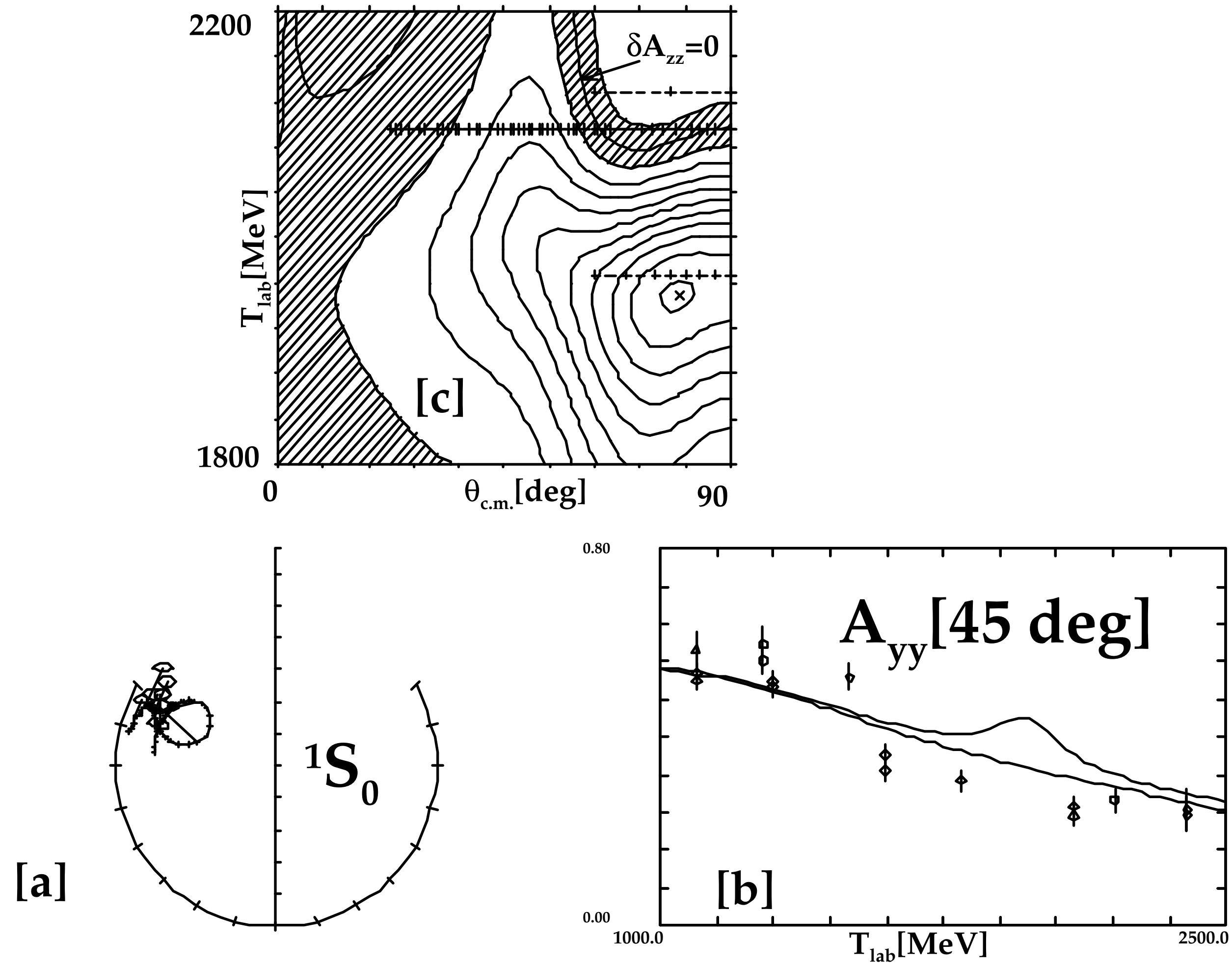
T_{lab}[MeV]
T_{lab}[MeV]


SM97/SM94
pp --> pp
θ = 45°+-1°
AL(97)
(a)
dσ/dΩ (mb/sr)
T (MeV)
SM97/SM94
pp --> pp
θ = 90°+-1°
AL(97)
(b)
dσ/dΩ (mb/sr)
T (MeV)



60
45
30
15
0
σ (mb)
SM97
σ^tot
BU(66)
σ^el
(a)
pp-->pp
0
800
1600
2400
T (MeV)
30
20
10
0
σ_R (mb)
(b)
SM97
VE(82)
BY(87)
pp-->pp
0
800
1600
2400
T (MeV)



2200
1800
δA_zz=0
T_lab[MeV]
[c]
0
θ_c.m.[deg]
90
¹S₀
[a]
0.80
0.00
A_yy[45 deg]
[b]
1000.0
2500.0
T_lab[MeV]